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Climate Change
and Extreme Weather

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More homes in the future will be vulnerable to rising global sea level and storm surges, including these marshfront structures at Tolers Cove Marina off the Ben Sawyer Blvd. in Mount Pleasant.

PHOTO/GRACE BEAHM

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Serving South Carolina

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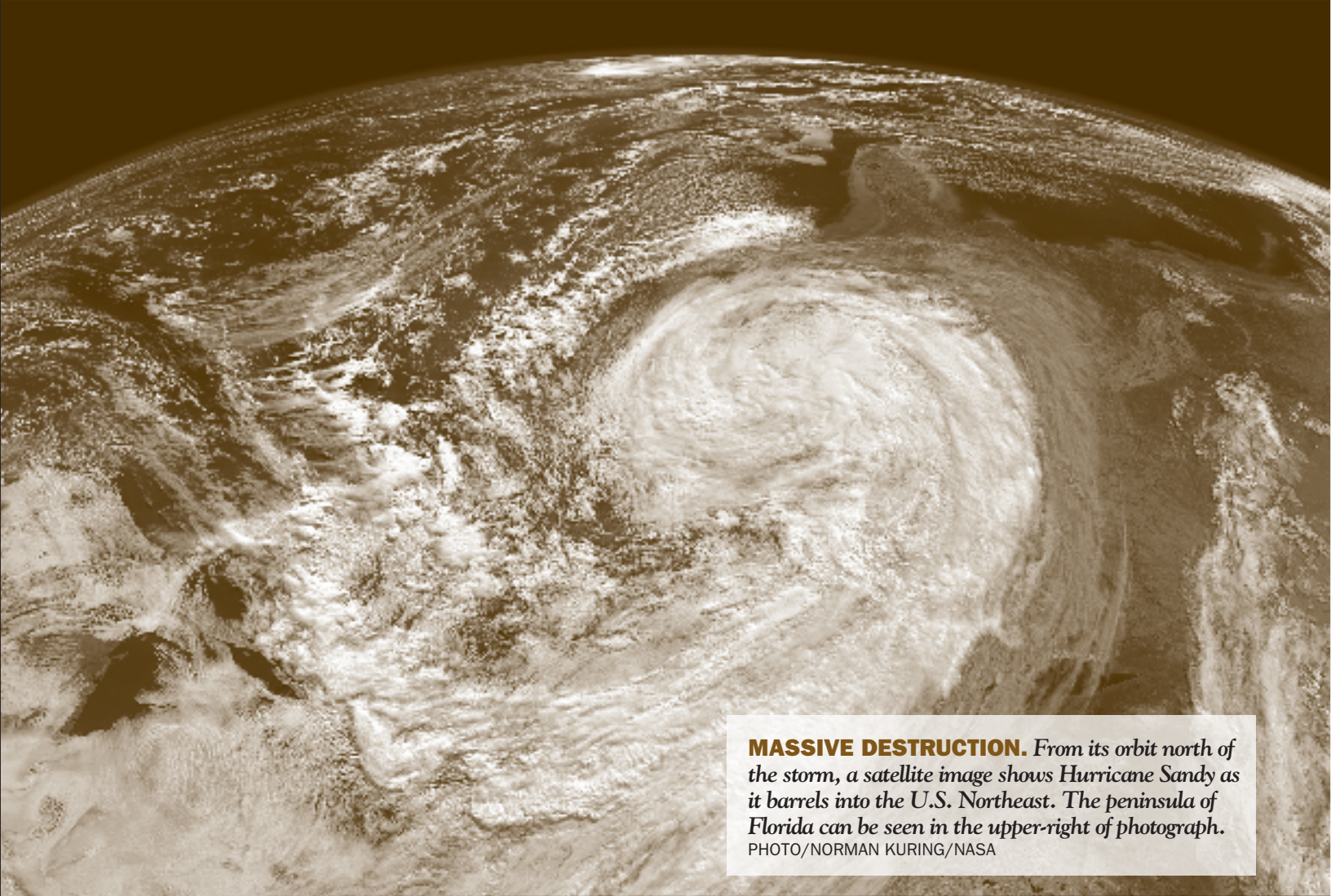
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MASSIVE DESTRUCTION. From its orbit north of the storm, a satellite image shows Hurricane Sandy as it barrels into the U.S. Northeast. The peninsula of Florida can be seen in the upper-right of photograph.

PHOTO/NORMAN KURING/NASA

Climate Change and Extreme Weather

by John H. Tibbetts

After Hurricane Sandy barreled ashore in October 2012, killing 100 people and causing an estimated \$65 billion in damages, politicians and pundits claimed that climate change is contributing to more intense storms and causing greater coastal flooding.

So were they correct?

Global warming is adding heat to the oceans and atmosphere. It's also increasing evaporation from the oceans, lakes, rivers, and soils. A warmer atmosphere holds more water vapor. In turn, storms, fueled by added heat and water vapor, are intensifying. This so-called "climate shock" has altered normal weather patterns in subtle and profound ways around

the world.

It's not accurate to say that climate change *causes* any particular record-breaking weather event. Each extreme in weather is caused by many factors.

But human-induced climate change is now one of those factors and sometimes the most important one, according to Donald Wuebbles, a climate scientist at the University of Illinois.

Climate change has become such a powerful influence in the Earth's climate system that its fingerprints are found from the poles to the equator and throughout the world's oceans and atmosphere.

"All weather is occurring against

the background of a changed climate," says Wuebbles, a lead author of a January 2013 public-review draft of a federal National Climate Assessment report, the most comprehensive peer-reviewed analysis of global warming in the United States. "A dominant influence on climate is human activity."

Natural weather extremes are still occurring, of course. But climate change increasingly functions as an accelerant—like pouring kerosene on a fire—making some natural extremes even more intense.

"When climate change is added to a natural extreme, their impacts together increase exponentially," says John Nielsen-Gammon, Texas state



ESCAPE. *This door window, recently replaced, at Berlin's for Men in downtown Charleston advertised the shop's air conditioning, once a rarity. Now, of course, air conditioning is commonplace, as are other increasing demands on power plants that release growing volumes of greenhouse-gas emissions into the atmosphere.*

PHOTO/GRACE BEAHM

climatologist and an atmospheric scientist at Texas A&M University. For instance, a combination of climate change and a natural extreme—La Niña—contributed significantly to the recent devastating drought in Texas, he says.

Consider other evidence of today's climate disruption. Summertime Arctic sea-ice melt is increasing, glaciers are rapidly melting, and major ice sheets are further destabilizing. Wild species continue to shift their ranges. Soils are losing moisture to evaporation, especially in dry regions, causing more intense droughts. Storm surges are rising and more beaches are eroding. Sea-surface temperatures are increasing, and ocean waters as deep as 2,300 feet are warming.

Not only was 2012 the hottest year on record in the United States, it also brought 11 different disasters that each caused more than \$1 billion in damage. Moreover, a continuing drought in the Midwest is on track to become the most expensive natural disaster in U.S. history.

Nor was the rest of the world spared. Intense flooding swamped

Bangladesh and the Philippines. Torrential rains hit China. A severe drought struck the African Sahel, a vast semi-arid region south of the Sahara Desert.

Greenhouse gas emissions, meanwhile, have exceeded the highest scenario projected by the 2007 United Nations Intergovernmental Panel on Climate Change (IPCC) assessment. Industrial society is producing more greenhouse-gas pollution than scientists forecasted at the time, largely because China's coal use has accelerated even faster than anticipated.

Certain categories of disasters—heat waves, heavy precipitation, drought, and storm surges—are most clearly enhanced by climate change. In the end, though, climate change's disruption has become so integrated in the Earth's systems that it influences many other weather extremes.

Two decades ago, most climate scientists viewed global warming as a slow, incremental phenomenon with unknown costs and effects to arrive at some point in the future.

Now, though, more scientists are speaking out with a new, uncharacter-

istic certainty. The Earth's climate has changed, they say. And this change is making some weather disasters more likely to occur.

Many weather disasters will continue to be shaped by natural variability, according to a special IPCC 2012 report on climate change and extreme weather.

But, in many cases, climate change has an important role, as well.

"A changing climate," notes the IPCC 2012 report, "leads to changes in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events."

CLIMATE IN HISTORY

To understand our modern climate disruption, look back about 250 years to a time when technological advances began radically reshaping the world.

In the 18th century, British mining companies sought more powerful machines to pump groundwater out of coal tunnels. At first, they used water wheels for energy but later developed steam engines modified from military cannons.

Coal or wood would be burned to heat water in a boiler until steam reached a high pressure and expanded, driving mechanisms to pump groundwater. The first steam engines, though, were inefficient and costly to operate. So most British industries continued to use the water wheel and horses as the primary sources of power.

By the 1770s, though, the Scotsman James Watt had designed more efficient steam engines, and investors brought his patented machines into production.

These engines provided energy for mines, factories, mills, and plantations. By the 1790s, some South Carolina planters were using steam engines on their estates to mill rice or gin cotton. Steam power allowed planters to process crops faster so they could cultivate more land and make bigger profits. Later, steam engines powered railroad locomotives and ships.

The steam engine and coal com-

bustion launched the Industrial Revolution in Britain. Coalfields were relatively close to centers of British industry, and coal was far cheaper, more plentiful, and more energy efficient than wood and charcoal.

For generations, while the steam engine drove unprecedented economic growth and raised living standards in many regions around the world, coal was easily the world's dominant fossil-fuel resource.

Oil production, though, got a boost in 1908 when the Ford Motor Company began manufacturing the Model T. It became the first inexpensive car built on assembly lines, and

produces carbon-dioxide emissions, which rise into the atmosphere and capture a portion of the re-radiated energy of the sun, increasing the temperature of the Earth.

We know that the rapid increase of carbon dioxide in the atmosphere over the past century has been driven by emissions from human activities. Carbon dioxide from combusting fossil fuels or burning forests has a particular isotope signature. This signature allows scientists to tease out background concentrations of carbon dioxide in the atmosphere from industrial society's contributions.

Atmospheric carbon dioxide is by far the strongest lever of global warming and global cooling. Other greenhouse gases include water vapor, methane, and nitrous oxide.

When the atmospheric concentration of carbon dioxide increases, the planet warms. When it decreases, the planet cools.

Scientists have their most complete understanding of the global climate over the past 800,000 years, primarily from ice-core records that have been confirmed from other sources. That's a

very long time in human history. Our species, *Homo sapiens*, did not emerge in Africa until about 200,000 years ago.

Along the span of the ice-core record, atmospheric carbon dioxide cycled up and down between about 180 parts per million (ppm) and about 280 ppm.

When atmospheric carbon dioxide dropped near 180 ppm, the Earth's climate turned very cold and giant ice sheets covered high-latitude landmasses in the Northern Hemisphere. When atmospheric carbon dioxide rose to 280 ppm about 11,500 years ago, world

climate was bathed in warm temperatures and glaciers retreated. It remained near 280 ppm for thousands of years until industrial society increasingly burned coal for energy production in the late 18th century.

Today, it's near 400 ppm—and rising. Over just two centuries, atmospheric carbon dioxide has increased 120 ppm beyond the highest concentration found in the ice-core record.

Even more troubling news is that atmospheric carbon dioxide continues to increase at an “exceptionally fast rate,” noted the 2007 IPCC assessment. It is annually increasing six-times faster than the historical average from 1750 to 2000, and it will soon increase seven-times faster and then eight-times faster and then nine-times faster, according to the IPCC.

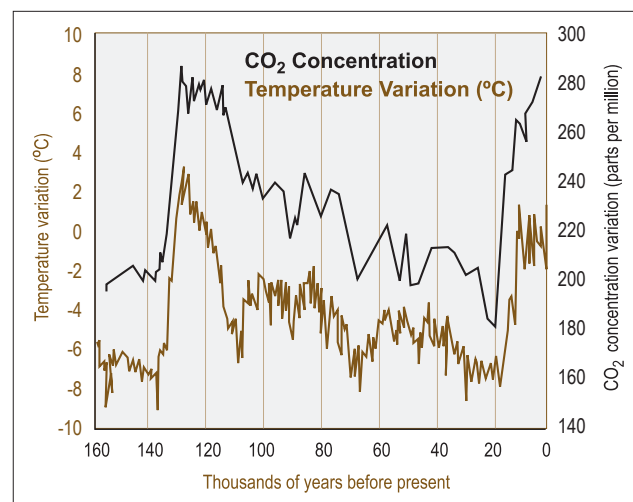
Looking deeper into the Earth's distant history, scientists have found epochs when atmospheric carbon dioxide was roughly the same level as it is today.

For example, some 15-to-20 million years ago, atmospheric carbon dioxide was in the 350-to-400 ppm range, notes Aradhna Tripathi, a climate scientist at the University of Southern California–Los Angeles. Tripathi and her colleagues explained in a 2009 study in the journal *Science* that global temperatures were 5-to-10° F (3-to-5.5°C) higher than today's, and sea level was approximately 75-to-120 feet higher.

When the Earth's atmospheric carbon dioxide increases, global temperature rises. And that's what is happening now. As expected by climate scientists, the Earth's surface temperature is responding sensitively to a dramatic and human-driven change in atmospheric chemistry.

Global temperature data collected on land, at sea, and later by satellite sensors show that average land and sea temperatures have warmed by 1.5° F (0.8° C) from the first decade of the 20th century to the first decade of the 21st century. Most of this warming has occurred since the late 1970s.

This warming will continue to



For hundreds of thousands of years, the rising and falling of carbon-dioxide concentrations were intertwined with the rising and falling of global average temperatures.

SOURCE/CLIMATE CHANGE POLICY: A SURVEY/ISLAND PRESS, 2002

imitators quickly followed suit.

By the 1950s, worldwide oil production finally caught up with coal production, and natural-gas fields were added to the resource mix.

Today, global industrial society mines and drills for carbon-intensive fossil fuels that it combusts for energy to power engines in our cars and trucks, electrical plants, factories, and farm tractors. About 80% of worldwide energy use and about 90% of U.S. energy use are derived from combusting fossil fuels.

Unfortunately, this combustion

accelerate for decades. On the current track of climate disruption, global temperatures could rise as high as 11° F (6° C) by 2100, according to the IPCC.

A hotter climate eventually drives up global sea level. Thermal expansion has accounted for about four inches of global sea-level rise over the past century. Loss of freshwater from glaciers and ice sheets accounts for the other four inches.

Recent studies, however, indicate that massive polar ice sheets in Greenland appear to be more signifi-

cant contributors to rising sea level than previously realized because the ice sheets are losing mass so quickly.

There's no question about the climate's long-term direction. Each time that the planet warmed, ice sheets have melted. The question now is how much and how fast they will melt.

Global sea level is expected to rise about two-to-four feet by 2100, according to the public-review draft of the federal National Climate Assessment report, though regional and local impacts will continue to be

widely variable.

A sea-level rise of about three feet by 2100 is the "slow, small, and expected" scenario that some policymakers are starting to include in planning, says Richard Alley, a climate scientist at Pennsylvania State University. But "we can't rule out catastrophic change" of 15-to-20 feet of sea-level rise by 2100. It's not likely to occur, he says, but scientists can't eliminate it as a possibility, either.

LISTENING TO THE ORBITS

The Earth's climate oscillates between cold eras—popularly known as ice ages—and the warm eras known as interglacials.

Ice ages usually last about 100,000 years, and the interglacials about 10,000 years, though some have lasted 5,000 and others 20,000 years. The most recent ice age ended about 11,500 years ago. Today, we are living in an interglacial period called the Holocene.

Periodic wobbles in the Earth's orbit around the sun have had the leading role in driving past major climate changes.

About 20,000 years ago, an orbital wobble allowed slightly more direct sunlight to warm the icy high-latitude regions of the Northern Hemisphere. Ice sheets at that time covered nearly a third of the world's landmass. In North America, they covered all of Canada and reached as far south as New York City.

Ice and snow reflect solar radiation, bouncing a portion of the sun's heat back into space and allowing the Earth to stay relatively cool. But when more direct summer sunlight touched northern Canada 20,000 years ago, portions of the ice sheet there began to melt. As a result, muddy ground, shallow lakes, and wetlands appeared, soaking up more heat.

During this long, slow melt, organic matter—roots, leaves, and aquatic plants—that had been frozen for tens of thousands of years began to rot.

Decaying organic material released



MATTER OF TIME. A man walks along the off ramp of Highway 61 going to West Ashley, where highways 17 and 61 split. High tide sometimes covers the road. Global sea level is expected to rise two-to-four feet by 2100, swamping many of today's roads and causeways.

PHOTO/GRACE BEAHM



BYGONE ERA. In 1882, G.D. Hazard photographed the Muir Glacier (left) in Alaska. The same location was photographed in 2005 by Bruce F. Molnia.

PHOTOS/GLACIER PHOTOGRAPH COLLECTION, NATIONAL SNOW AND ICE DATA CENTER, WORLD DATA CENTER FOR GLACIOLOGY

carbon dioxide and methane into the atmosphere, which in turn trapped more heat energy from the sun, which in turn further thawed northern Canada ice sheets, which stimulated decay of more organic matter, which released additional carbon and methane—a classic case of a feedback loop.

From this northern Canada feedback loop emerged an immensely complex series of climatic changes, particularly in the oceans where vast volumes of carbon dioxide were released into the atmosphere. This ocean-to-atmosphere transfer of carbon dioxide drove a global warming that lasted almost 10,000 years—until the Earth emerged into the current Holocene interglacial.

It all began, though, with that wobble in the Earth's orbit.

"Everything is listening to the orbits," says Alley. The Earth's most sensitive listening post has been north-

ern Canada. "When ice grows in Canada," says Alley, "the whole world gets colder. When ice melts in Canada, the whole world melts."

Today, high-latitude landmasses of the Northern Hemisphere, including northern Canada, are warming faster than any other terrestrial areas on Earth. But this time the Earth's orbit is not solely in charge. The Earth's climate now has another powerful master: industrial society and its greenhouse-gas emissions.

THE LONG SWEAT

Broiling high noon—August in South Carolina. Your body responds to higher temperatures by pumping moisture to your skin's surface. As sweat evaporates from your skin, it changes from a liquid to a vapor, a process that cools you off. As afternoon temperature rises, your body perspires even more. By

mid-afternoon, your skin is as wet and slippery as a seal's.

That's how your body regulates its heat—by delivering moisture to your skin's surface where it evaporates and cools.

The Earth's surface has a similar cooling process. The world's oceans cover more than two-thirds of the Earth's surface, absorbing more than 90% of the heat energy captured by greenhouse gases. As daytime temperatures soar, oceans release more moisture into the atmosphere to cool the surface. As the Earth's surface temperature has increased over decades because of climate change, evaporation has also intensified, drawing more water vapor into the atmosphere.

Because of climate change since the 1970s, there has been a 4% increase in global water vapor, a powerful greenhouse gas.

Intensifying evaporation also robs



TORRENTIAL. *Danny Moore struggles through the flood on King and Huger streets on peninsular Charleston as heavy rains stopped traffic on August 28, 2012. The warmer global atmosphere holds more water vapor, which is released in heavier downpours.*

PHOTO/GRACE BEAHM/THE POST AND COURIER

moisture from surface soils, parching landscapes and causing devastating droughts and wildfires. Longer and deeper droughts have occurred over wider areas worldwide since the 1970s, especially in the tropics and subtropics, according to the IPCC.

Meanwhile, atmospheric currents and winds are redistributing water vapor from water-poor regions to water-rich regions where this moisture is released as rain or snow in heavier storms.

A warming climate, then, increases the likelihood of extremes in precipitation: drought (where it doesn't rain) and floods (where it rains a lot) but in different places and at different times.

It's also raining harder when it finally does rain, even in some dry places. Because a warmer atmosphere holds more water vapor, it is more available to low-pressure systems when they roll in, resulting in more violent downpours. Heavier rains run quickly off surfaces into waterways instead of filtering into soils and recharging groundwater.

Some North American lakes, meanwhile, are shrinking because of increased evaporation. Until recently, parts of South Carolina, especially the

upstate, experienced a severe, near-decade-long drought, which drove water levels at some lakes to record lows.

"We have avoided a major water crisis," says Hope Mizzell, the South Carolina state climatologist. "But there is growing demand for the resource. There are many more of us now, and a lot more stress on the system."

The ocean and atmosphere are tightly coupled. Together they produce ocean waves, trade winds, storm surges, ocean currents, upper-atmospheric currents, land-sea breezes, tropical cyclones, monsoons, and many other phenomena. The Earth's water-pumping systems are also tightly integrated with its heat-pumping systems.

So all are interwoven: ocean, atmosphere, soils, global heat, global water vapor, carbon dioxide. Pull one thread and it affects many others.

"We're changing the environment — it's very clear," Thomas R. Knutson, a research meteorologist with the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory, has said. "We're changing global temperature, we're changing atmospheric moisture, we're changing a lot of things. Humans are

running this experiment, and we're not quite sure how it's going to turn out."

OSCILLATIONS AND EXTREMES

Climate change over time is heading in just one direction—toward more warming. But natural climate oscillations—well, they oscillate.

There are several major climate cycles that powerfully influence U.S. weather, including the El Niño-Southern Oscillation (ENSO), the North Atlantic Oscillation, and the Madden-Julian Oscillation.

ENSO, perhaps the best known of these cycles, is a phenomenon of the Pacific Ocean and atmosphere that causes dramatic weather extremes around the world, including droughts, wildfires, and Atlantic hurricanes.

ENSO is perhaps the Earth's most powerful agent of extreme weather.

There are two components of ENSO. El Niño—or "the little boy" in Spanish—occurs every three to seven years when easterly trade winds fall off and unusually warm, low-pressure systems get trapped in the central equatorial Pacific Ocean.

As this stretch of ocean simmers, huge columns of heat and water vapor are drawn up into the atmosphere, spawning thunderstorms and tropical cyclones.

In turn, these pistons of moist heat are driven upward into the cold winds that race easterly across the dome of the world. It is El Niño's pressure that shoves the jet stream into a higher gear, doubling its speed. Thousands of miles away, a faster and more powerful jet stream chops off the heads of giant Atlantic Ocean thunderclouds, hurricanes-in-making, that form off the west coast of Africa in a process called "vertical shear."

That might be a bit of consoling news for South Carolinians. If global warming over this century strongly enhances El Niño and other ocean-atmosphere oscillations, it could make Atlantic hurricanes *less likely* to occur.

But Atlantic hurricanes that do manage to form will be more likely to

be intense ones. That's because warmer North Atlantic water—if every other factor is equal—energizes hurricanes. The warmer the Atlantic, the stronger a hurricane becomes. Indeed, climate models indicate that Atlantic hurricanes are likely to be more intense but less frequent over the 21st century.

La Niña (“the little girl”) is the other half of ENSO, but it occurs only about half as often. A La Niña event begins when colder than normal sea-surface temperatures arrive in the central equatorial Pacific Ocean, and increased atmospheric moisture moves into the western Pacific.

La Niña, which also strongly affects the world's atmospheric currents, has a powerful influence on North American weather, pushing easterly storm tracks and moisture farther north than usual.

In the United States, this diverting of water vapor and low-pressure systems typically causes droughts through the Sun Belt from Southern California and Arizona across to South Carolina.

It was a combination of global warming and a strong La Niña event that combined to create a record-setting drought and heat wave in Texas in 2010-2011, according to John Nielsen-Gammon, the Texas state climatologist.

This kind of double whammy—climate change teaming up with natural extremes—is a troubling model for the future, notes Kevin E. Trenberth, a senior scientist with the National Center for Atmospheric Research in Boulder, Colorado, and a lead author of the 2007 IPCC assessment.

When natural climatic extremes and global warming synchronize in the

same direction, they shatter weather records, Trenberth writes in the journal *Climatic Change*.

In contrast, when a natural extreme and climate change are going in opposite directions, they can cancel out one another, resulting in mild or uneventful weather. As a result, climate change can be masked for years. People tend to let their guard down, thinking that climate change has lost momentum. Eventually, though, natural climatic extremes and global warming will synchronize, and weather records will be shattered once more.

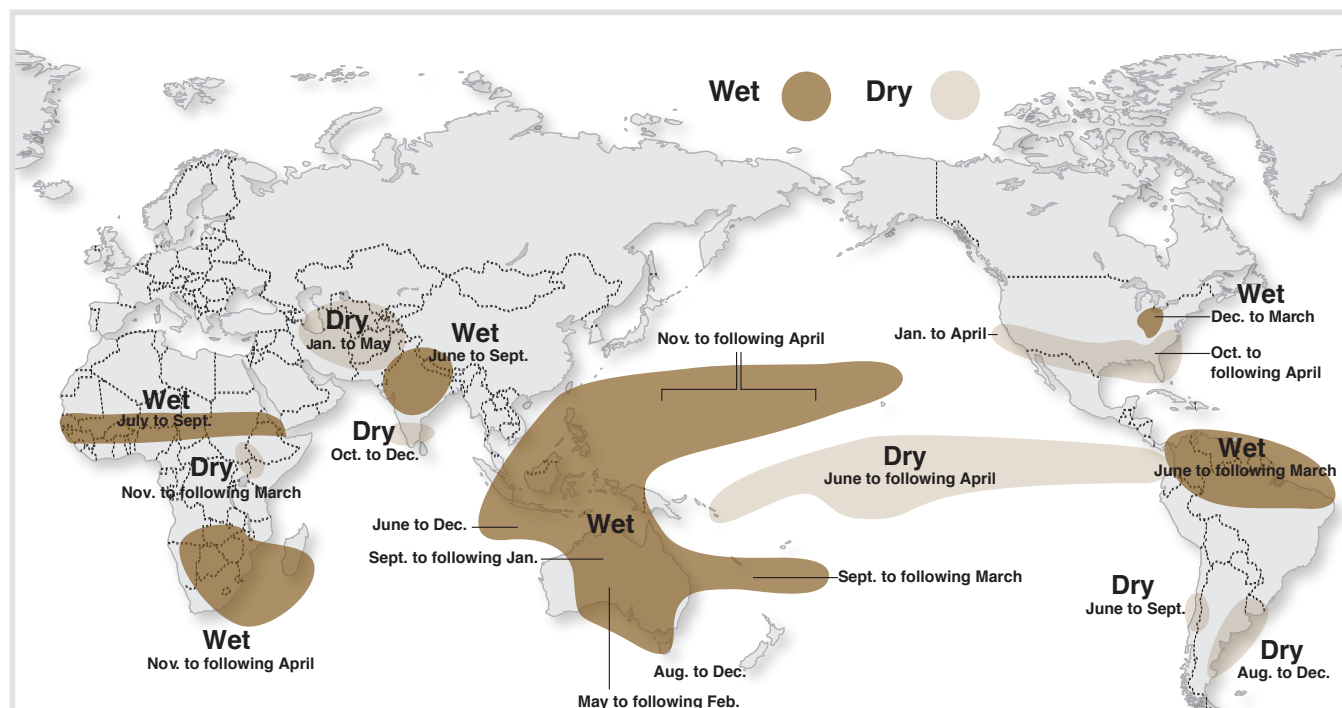
SANDY AND SEA LEVEL

Is Sandy, after all, the harbinger of future storms and coastal flooding in a warmer climate?

Sandy was the largest Atlantic

La Niña and Rainfall

La Niña conditions in the tropical Pacific are known to shift rainfall patterns in many different parts of the world. Although varying somewhat from one La Niña to the next, the strongest shifts are fairly consistent in the regions and seasons shown on the map below.

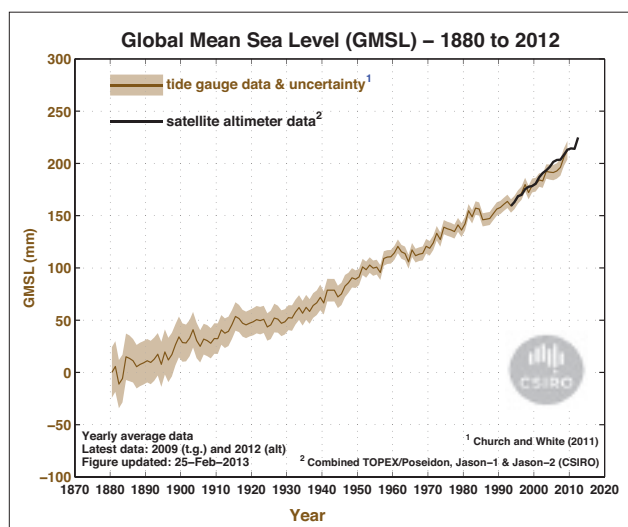


For more information on La Niña and El Niño, go to <http://iri.columbia.edu/ENSO>

Sources: Ropelewski, C. F. and M. S. Halpert, 1989: Precipitation patterns associated with the high index phase of the Southern Oscillation. *J. Climate*, 2, 268-284, Mason and Goddard, 2001: Probabilistic precipitation anomalies associated with ENSO. *Bull. Am. Meteorol. Soc.* 82, 619-638

In 2010-2011, an especially strong La Niña contributed to intense droughts along the southern tier of states from southern California to the Carolinas.

SOURCE/INTERNATIONAL RESEARCH INSTITUTE



Satellite data show that global sea level rise has accelerated since the early 1990s.
GRAPHIC/NEIL WHITE/CSIRO

hurricane on record in geographic terms, spanning 1,100 miles. It was also the second-most expensive hurricane in U.S. history, trailing only Katrina in 2005. And Sandy was freakishly powerful for an autumn storm striking the U.S. Northeast, teaming up with another dangerous weather system to make a rare “superstorm.”

But giant hurricanes do occur naturally, of course—and they have periodically hit the U.S. Northeast. So how much did our changing climate affect Hurricane Sandy’s power and destruction?

Since the 1970s, climate change has established new baseline conditions of increased atmospheric water vapor and higher North Atlantic Ocean sea-surface temperatures. These baseline conditions likely enhanced Sandy’s size and intensity, scientists say—but the extent of that enhancement is still debated.

Global sea level has risen over the past century, which affected Sandy’s destructive energy across coastlines. There’s no debate about that. Sandy’s highest surge of 14 feet crashed into lower Manhattan near a water-level monitoring station that has recorded about one foot of sea-level rise since 1900.

One-third of that rise—about four inches—has been caused by natural

land subsidence since the early 20th century. Coastal land continues to sink because gravity is packing ancient delta sediments tighter and tighter.

But global warming, by melting ice sheets and expanding seawater, has caused the other two-thirds of global sea-level rise—or about eight inches. Satellite observations, moreover, point to an apparent increase in the rate of global sea-level rise since

the 1990s.

Scientists have found that even “small increases in sea level over the past few decades already have increased the height of storm and wind-waves” in many U.S. coastal regions, notes a December 2012 report published by the NOAA Climate Program Office.

So how high should we build new structures to accommodate sea-level rise?

In 2010, the North Carolina Coastal Resources Commission’s

Science Panel on Coastal Hazards recommended that the commission begin planning for a target of three feet of sea-level rise by the year 2100.

But that might not be realistic because “almost no one plans for events 90 years into the future,” notes Spencer Rogers, a coastal construction and erosion specialist with the North Carolina Sea Grant program, in a July 12, 2012 advisory letter.

It’s more feasible for households to plan over a shorter-term—30 years. In North Carolina, a 30-year timeframe for a household could bring an estimated eight inches of sea-level rise by 2040, taking into account historical data and a potential acceleration by climate warming.

“If you’re a homeowner or a small-business owner, 30 years is a reasonable amount of time to plan,” says Jessica Whitehead, regional climate extension specialist with North Carolina and South Carolina Sea Grant programs. “It’s difficult for individuals to think much beyond that.”

Thirty years is the length of a typical home mortgage. So when building a home along the coast or retrofitting an older one, it would be wise to remember that three decades in the future sea level would likely be



CLIMATE STUDENTS. The Kitchen Table Climate Study Group, a volunteer organization of a few dozen citizen-activists from McClellanville and surrounding rural areas, gather monthly to keep up-to-date on scientific findings on climate change.
PHOTO/WADE SPEES



PREPARED. *These elevated homes under construction are located at the Hunley Waters development on Hunley Waters Circle near Park Circle in North Charleston.*

PHOTO/GRACE BEAHM

several inches higher, depending on many factors.

Some communities stipulate that the first elevated floor of any new or substantially rebuilt coastal home must be built a foot higher than the minimum required elevation in the local flood regulations. That higher elevation above the requirement is called “freeboard.”

Since March of 2012, for instance, the North Carolina Residential Building Code amendments have required one foot of freeboard for all new houses in the state.

Adding more than one foot of freeboard could be a good idea, depending on the structure’s location. After Hurricane Ike struck the low-elevation Bolivar Peninsula along the Texas coast in September 2008, researchers found that surviving homes typically had habitable first floors two-to-four feet higher than minimum floodplain requirements, according to Rogers.

Governments, unlike households,

have to look further ahead than 30 years. Policymakers around the country are planning to build or retrofit many roads, bridges, airports, sewage-treatment plants, and railroad infrastructure—all of which tend to be 50-year investments.

Although global sea level will continue to rise, no one can say how rapidly it will do so over the next half-century. Moreover, each coastal location is unique. Some shorelines are already eroding rapidly; others have widening beachfronts.

“We have and will continue to see different rates of sea-level rise in different places,” says S.C. Sea Grant researcher Paul Gayes, a marine scientist and director of the Center for Marine and Wetland Studies at Coastal Carolina University. “Global change doesn’t mean that everybody gets the same experience nor necessarily at the same time.”

Polls taken after Sandy show that the public increasingly recognizes

climate change as a driver of more extreme weather events and coastal floods. Residents of the densely populated U.S. Northeast, especially New York City, the nation’s cultural and economic capital, are talking about climate change in a new way.

In July 2013, Mayor Michael Bloomberg unveiled a \$20 billion plan to protect New York City from future floods associated with climate change. The plan includes 250 recommendations ranging from new floodwalls and storm-surge barriers to flood-proofing the city’s power and telecommunications infrastructure.

“Superstorm Sandy has been a game-changer,” says James McCarthy, an oceanographer at Harvard University. “It has connected the dots to a lot of people. That a hurricane could come up the East Coast and continue to intensify in near-record warm temperatures over the past 100 years enabled people to imagine a future of more intense storms.” 🐦

New flood maps and premium changes coming

Many owners of older, low-elevation structures in South Carolina could face sticker shock when they see their flood-insurance bills over the next several years.

After numerous major hurricanes and other disasters over the past decade, the federal flood-insurance program was swimming in red ink. On July 6, 2012, a new law passed by Congress made significant reforms to the program, including eventual elimination of all subsidies.

The National Flood Insurance Program (NFIP) will roll out new preliminary flood-risk maps in communities around the country over the next year. These maps will provide information to be used by NFIP to update insurance policies.

New homes and other structures in flood-risk areas already must be elevated on pilings or by other means to meet NFIP requirements. Elevating the first habitable floor of a structure is a cost-effective way to avoid destructive floods.

But thousands of structures built decades ago were grandfathered into the program and given low-cost insur-

ance premiums without an elevation requirement.

"We saw this problem during Hurricane Sandy," says Thomas J. McGuire, the floodplain management coordinator for Charleston County. "There were a lot of homes in older, developed areas on Staten Island and other places that predated [the federal flood insurance rules], and they weren't elevated. They didn't have proper foundation systems, and many property owners thought they were not susceptible to coastal flooding."

Subsidies are being phased out for second homes, rental houses, and commercial properties that were not raised on pilings or new foundations and were built before the federal flood-insurance program came into effect in 1968. Subsidies for severe repetitive-loss properties will be phased out later in 2013.

By late 2014, all subsidies are supposed to go away, but they would not go into effect right away for some homeowners, according to Maria Lamm, the NFIP coordinator for South Carolina.

Many properties covered by exist-

ing subsidies would continue to be charged lower rates until they are sold or if policies are allowed to lapse. (Check with your insurance agent. The Federal Emergency Management Agency runs the program, but private insurers administer policies.)

Premiums for low-elevation structures in vulnerable locations would get significantly more expensive. Think of an older home built on a slab not far from the beachfront with coverage of \$250,000 on the structure and \$100,000 on the contents. Let's say that the first inhabited floor is three feet under the designated "base-flood elevation" in a high-risk VE zone.

The owner of this building would eventually face an annual premium of \$18,354, according to Spencer Rogers, a coastal construction and erosion specialist with the North Carolina Sea Grant program. That would be an increase of 142% over the previous premium of \$7,454.

Rate increases, however, would be limited to 25% annually until the accurate flood-risk premium is reached.

The 2012 law will change premiums on many structures far inland. ♡



Reading and Websites



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Steroids and carbon dioxide—the wisdom of metaphor

Americans like sports metaphors. “That’s a slam dunk.”

“You need to step-up to the plate.”

“They’re playing hardball.”

Metaphors are colorful and vivid, helping us find threads of meaning in a confusing world. When we use a metaphor, we try to translate an abstract idea into something familiar, concrete, and dynamic. Sports metaphors are especially powerful because they clearly express action when there seems to be so little.

Climate scientists have long used metaphors to describe global warming. The term “greenhouse effect” helps us visualize how the atmosphere captures a portion of the sun’s energy. Carbon dioxide, in turn, is called a “greenhouse gas.”

These metaphors are effective cognitive aids, allowing us to visualize a process that can’t be seen directly by the naked eye. But metaphors can mislead and over-simplify. So their potential effectiveness must be balanced against their potential for misuse.

These days, scientists and science journalists are using a sports metaphor to explain how global warming enhances the likelihood of weather-related disasters.

Carbon dioxide is one of the “steroids of heat-trapping gases” that increase global warming, according to a January 2013 public-review draft of a federal National Climate Assessment report to be finalized in late 2013.

In March 2013, members of an Australian government commission called on to address climate change and adaptation said that the nation should begin preparations for a

“climate on steroids.”

Is an athlete injecting steroids similar to industrial society’s emissions of greenhouse gases into the atmosphere? In each case, adding certain chemicals to a particular system (a human body, the Earth’s atmosphere) significantly increases that system’s capacity to reach extreme events more frequently.

Using steroids allows athletes to build and repair muscle mass. It won’t allow a talented player to hit a homer every time at the plate. But in McGuire’s case, his steroid use allowed him to nearly double his *likelihood of experiencing an extreme event*—hitting a home run—whenever he batted.

Adding greenhouse gases to the atmosphere, meanwhile, increases humanity’s *likelihood of experiencing extreme events* such as floods and storms.

As the surface of the Earth warms, it stimulates evaporation from the oceans, lakes, and soils. The atmosphere, then, becomes warmer and moister, creating conditions for more frequent and extreme weather: storms, floods, and heat waves. Ice sheets are also melting faster as the Earth warms, raising global sea level, which is increasing the likelihood of coastal flooding.

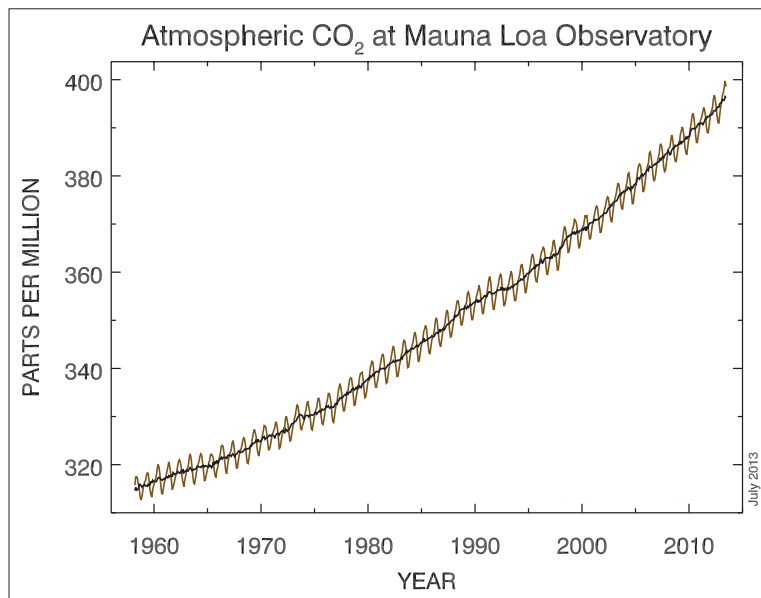
So, is the steroid metaphor an effective one?

“Different stories connect with different people,” says Chris Field, a climate scientist at the Carnegie Institution and Stanford University. “And people like baseball.”

But a home run is not a risk, he says. The most important thing for the public to understand, he says, is that climate change increases the likelihood of extreme weather events.

A major flood is dangerous and potentially deadly. A hurricane destroys homes and damages communities. But the steroid/sports metaphor, Field says, lacks this element of risk. “A home run,” he adds, “is a good thing.”

Not if you’re the opposing pitcher. ♡



Atmospheric carbon dioxide at Mauna Loa Observatory, Hawaii, has risen dramatically since measurements began there.

GRAPHIC/SCRIPPS INSTITUTION OF OCEANOGRAPHY AND NOAA EARTH SYSTEM RESEARCH LABORATORY

Perhaps the most famous example of steroid use occurred from the mid-1990s to 2007 in major-league baseball. Remember Mark McGuire? After smashing home-run records in the late 1990s, he retired in fame and glory. But years later he confessed to having used steroids to increase his performance.

When McGuire was healthy during the first six years of his career, he had about 600 plate appearances and 33 home runs per year. Each time he came to the plate he had about a 1-in-18 likelihood of hitting a homer. But during 1996 to 1999, McGuire averaged 61 homers per year, raising his chances of hitting home runs to 1-in-10.

NEWS & NOTES

Scientific records to illuminate food chain

Two of the South Carolina coast's finest scientific records could illuminate complex relationships among tiny but ecologically important creatures—oyster and goby larvae—in estuaries as global climate changes.

Goby larvae inhabit the water column of tidal creeks and eat oyster larvae, selecting them from other plankton. In turn, recreationally important species such as red drum and flounder consume gobies and other small fishes.

Now Sea Grant scientists are studying two data sets taken over more than 30 years from the North Inlet estuary in Georgetown County. The researchers are investigating how increasing water temperature has affected the reproduction, survival, and interactions among oysters and gobies and what impacts these changes might have on the estuary's food chain.

"We're interested in how or if the dynamics among oysters and gobies have changed, whether for good or for bad," says Juliana Harding, a marine biologist at Coastal Carolina University.

Worldwide, many natural communities are being altered as the climate changes. For instance, some prey species are becoming available at different times from their historical predators.

Harding is collaborating with Dennis Allen, director of USC's Baruch Marine Field Laboratory (BMFL). In North Inlet, Allen and his colleagues have measured winter water temperatures, which indicate an in-

crease of 1.7°C (3.1°F) from 1979-2012, a very rapid warming over such a brief period.

Since 1981, BMFL scientists have also collected zooplankton from the water column. Every two weeks, they have taken samples at the same location, the same stage of the tide, and the same time of day. Larval gobies are one of the more plentiful animals in those collections from May through September each year.

Now, with these two important data sets—winter water temperature and zooplankton abundance—scientists are studying whether the relative timing of goby and oyster larvae in the water column has changed and, if so, what that might mean for both populations. If winter water temperatures increase, will there be a mismatch between predators and the availability of their prey?

One interesting observation from the long-term record at North Inlet is that gobies are hatching later in the spring than expected, when water temperature is warmer. Potential long-term changes in the seasonal availability of oyster larvae are being evaluated using the archived collections.

Ongoing feeding experiments in the laboratory are examining goby larvae consumption of oyster larvae versus other possible planktonic prey. These experiments will provide new insights into the patterns, rates, and mechanisms of changes for these populations and habitats as water temperature continues to warm.

Changes between these two ecologically important species could have ripple effects on other ecosystem relationships, and thus have an impact on estuarine food webs in South

Carolina's tidal creeks, salt marshes, and bays. ♡

Coastal Heritage wins awards



Coastal Heritage recently won four prestigious awards. It won an Award of Merit in the 2012-13 International Summit Awards in the Society for Technical Communication competition. *Coastal Heritage* previously won a Distinguished Award at the chapter level.

Coastal Heritage also won 2nd place in the National Association of Government Communicators 2013 Blue Pencil/Gold Screen competition in the writer's portfolio division. This annual international awards program recognizes superior government communication products and those who produce them.

Another national competition sponsored by APEX in 2012 gave *Coastal Heritage* an Award of Excellence in the magazines and journals category. Current and back issues of *Coastal Heritage* are available

NEWS & NOTES

on the Consortium's website at www.scseagrant.org/products. ✓

Stormwater ordinance adopted

Jasper County was the recipient of a \$5,000 award from the Consortium's Sustainable Coastal Communities Initiative to support the county's stormwater management program.

The grant, which required an equal amount in match funding, enabled the county to develop a manual of best management practices and adopt a stormwater ordinance to reduce impacts of future development. The manual and ordinance will ensure that stormwater quality and quantity are maintained at pre-development levels.

Jasper County is predominantly rural, but has experienced a 20% population increase from 2000 to 2010. Municipal staff recognized the need for sustainable growth and the importance of implementing a stormwater management program to address issues associated with development.

For more information about this initiative, contact the Consortium's Coastal Communities Extension Specialist April Turner at (843) 953-2073 or april.turner@scseagrant.org. To view other projects supported under the initiative, visit the Coastal Communities webpage at www.scseagrant.org/content/?cid=42. ✓

2012 S.C. Environmental Awareness Award winner announced

Tom Kester, a retired partner from

the global auditing firm of KPMG LLP, was named winner of the 2012 S.C. Environmental Awareness Award during a ceremony May 15 at Harbison State Forest in Columbia. Mr. Kester, who serves as chairman and treasurer of the not-for-profit Conestee Foundation, was recognized for his volunteer efforts as part of the Foundation to acquire an old mill lakebed and turn it into a wildlife refuge and nature park for public use.

Lake Conestee Nature Park (LCNP) in Greenville consists of over 400 acres, which includes the original mill lakebed and three historic farm properties adjacent to the lakebed. There are over 10 miles of trails built within the park and two outdoor learning centers. The creation of LCNP spurred local governments to restore an abandoned minor league baseball stadium to little league standards, and build four new little league baseball fields, creating a first class tournament site.

There have been over 15 Master's and Ph.D. studies done at LCNP. LCNP currently has grants from 3M and Michelin to design and install four instructional trail loops within the park. In addition, LCNP has been the recipient of numerous Eagle Scout projects. More information about the LCNP and the Conestee Foundation is available at www.conesteeperk.com.

The S.C. General Assembly established the S.C. Environmental Awareness Award in 1992. The award is now in its 20th year recognizing outstanding contributions made toward the protection, conservation, and improvement of South Carolina's natural resources. The S.C. Environmental Awareness Award Committee includes appointees from each of the following natural resource agencies: S.C. Department of Natural Resources, S.C. Sea Grant Consortium, S.C. Forestry Commission, and the S.C. Department of Health and Environmental Control. ✓



Col. Alvin A. Taylor, executive director of the S.C. Department of Natural Resources, presents the 2012 S.C. Environmental Awareness Award to Tom Kester for his volunteer efforts as chairman and treasurer of the Conestee Foundation.

PHOTO/STEWART GRINTON/S.C. DEPT. OF NATURAL RESOURCES



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EBBS & FLOWS

25th Annual Beach Sweep/River Sweep

Statewide, South Carolina
September 21, 2013

Join S.C. Sea Grant Consortium and S.C. Department of Natural Resources for the 25th annual Beach Sweep/River Sweep on Saturday, September 21, 2013. Last year, over 4,125 dedicated volunteers statewide removed 20 tons of debris from our beaches, marshes, and waterways.

To volunteer on the coast, contact Susan Ferris Hill at (843) 953-2092 or susan.ferris.hill@scseagrant.org. To volunteer inland, contact Bill Marshall at (803) 734-9096 or marshallb@dnr.sc.gov. For more information, visit www.scseagrant.org/Education.

Water Education Summit

Chattanooga, Tennessee
September 24-26, 2013

This summit is an opportunity to learn from leading educators working to improve water resources protection and management. Topics include private well protection, youth education, watershed planning, and low-impact development. The summit will emphasize innovative approaches for using information, technology transfer, and hands-on learning experiences to inspire water stewardship.

Visit www.h2osummit.org or contact Cal Sawyer at calvins@clemson.edu or (864) 656-4072 for more information.

S.C. Marine Educators Association Conference

Charleston, South Carolina
November 1-2, 2013

The theme of this 25th annual conference is "A Look into the Future of Ocean Science." Marine educators from around the state will explore ocean science research and technology that is changing what is known about the marine environment.

Keynote speaker Dr. Leslie Sautter from the College of Charleston will describe her adventures aboard the research vessel *Thomas G. Thompson*.

For more information, visit www.scmarineed.org or contact Blaik Keppler at kepplerb@dnr.sc.gov or (843) 953-9024.

Subscriptions are free upon request by contacting: Annette.Dunmeyer@scseagrant.org

ATTENTION SCHOOL TEACHERS! The S.C. Sea Grant Consortium has designed supplemental classroom resources for this and past issues of *Coastal Heritage* magazine. *Coastal Heritage Curriculum Connection*, written for K-12 educators and their students, is aligned with the South Carolina state standards for the appropriate grade levels. Includes standards-based inquiry questions to lead students through explorations of the topic discussed. *Curriculum Connection* is available online at www.scseagrant.org/education.